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NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

Flight Data Recorder Specialist's Factual Report

19 Pages

NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, D.C. 20594

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Flight Data Recorder

Specialist's Factual Report
By Charles Cates

1. EVENT SUMMARY

Location: Philadelphia, Pennsylvania
Date: April 17, 2018
Aircraft: Boeing 737-700
Registration: N772SW
Operator: Southwest Airlines
NTSB Number: DCA18MA142

On April 17, 2018, at 1103 eastern daylight time, Southwest Airlines flight 1380, a Boeing 737-7H4, N772SW, experienced a left engine failure and loss of engine inlet and cowling during climb at about flight level 320. Fragments from the engine inlet and cowling struck the wing, fuselage, and one cabin window, resulting in a depressurization. The flight crew conducted an emergency descent and diverted into Philadelphia International Airport (KPHL), Philadelphia, Pennsylvania. Of the 144 passengers and five crewmembers onboard, one passenger received fatal injuries and eight passengers received minor injuries. The airplane sustained substantial damage. The regularly scheduled domestic passenger flight was operating under Title 14 *Code of Federal Regulations* (CFR) Part 121 from LaGuardia Airport (KLGA), Queens, New York, to Dallas Love Field (KDAL), Dallas, Texas.

2. FLIGHT DATA RECORDER GROUP

A flight data recorder (FDR) group was not convened.

3. FDR Carriage Requirements

The event aircraft, N772SW, was delivered on July 7, 2000, and was operating such that it was required to be equipped with an FDR that recorded, at a minimum, 34 parameters, as cited in 14 CFR Part 121.344(d).

4. DETAILS OF FDR INVESTIGATION

The National Transportation Safety Board (NTSB) Vehicle Recorder Division received the following FDR:

Recorder Manufacturer/Model: **Honeywell 4700 256 wps**
Recorder Serial Number: **SSFDR-10933**

4.1. Honeywell 4700 256 wps Description

The Honeywell solid state flight data recorder (SSFDR) records airplane flight information in a digital format using solid-state flash memory as the recording medium. The SSFDR can receive data in the ARINC 573/717/747 configurations and can record a minimum of 25 hours of flight data. It is configured to record 256 12-bit words of digital information every second. Each grouping of 256 words (each second) is called a subframe. Each subframe has a unique 12-bit synchronization (sync) word identifying it as subframe 1, 2, 3, or 4. The sync word is the first word in each subframe. The data stream is "in sync" when successive sync words appear at proper 256-word intervals. Each data parameter (for example, altitude, heading, and airspeed) has a specifically assigned word number within the subframe. The SSFDR is designed to meet the crash-survivability requirements of TSO-C124a.

4.1.1. Recorder Condition

The recorder was in good condition and the data were extracted normally from the recorder.

4.1.2. Recording Description

The FDR recording contained approximately 27 hours of data. Timing of the FDR data is measured in subframe reference number (SRN), where each SRN equals one elapsed second. The event flight was the last flight of the recording and its duration was approximately 53 minutes. The parameters evaluated for the purpose of this report appeared to be in accordance with federal FDR carriage requirements.

4.1.3. Engineering Units Conversions

The engineering units conversions used for the data contained in this report are based on documentation from the aircraft manufacturer. Where applicable, the conversions have been changed to ensure that the parameters conform to the NTSB's standard sign convention that climbing right turns are positive (CRT=+).[1]

Table A-1 lists the FDR parameters verified and provided in this report. Additionally, table A-2 describes the unit and discrete abbreviations used in this report.

4.1.4. Non-Computed Data (NCD) Pattern

When the engine or APU controller lost power a non-computed data (NCD) pattern was seen in parameters sourced from that controller. The NCD pattern is indicative that the raw data was no longer reliable or not available and is normal in this circumstance. Engine and APU parameters with NCD included throttle resolver position, VSV position, VBV position, PS3, EGT, fuel flow, oil temperature, and oil pressure.

[1] CRT=+ means that for any parameter recorded that indicates a climb or a right turn, the sign for that value is positive. Also, for any parameter recorded that indicates an action or deflection, if it induces a climb or right turn, the value is positive. Examples: Right Roll = +, Pitch Up = +, Elevator Trailing Edge Up = +, Right Rudder = +.

4.2. Time Correlation

Correlation of the FDR data from SRN to the event local time, eastern daylight time (EDT), was established by using the recorded Time GMT[2] hours, Time GMT Minutes, and Time GMT Seconds and then applying an additional four hours offset to change GMT to EDT.

Accordingly, the time offset for the event flight data from SRN to local EDT is the following:

EDT = SRN – 57024.625.

Therefore, for the rest of this report, all times are referenced as EDT, not SRN.

4.3. FDR Plots and Corresponding Tabular Data

Figures 1 to 11 contain FDR data recorded during the April 17, 2018 event. All the parameters listed in table A-1 are plotted except Time Clock GMT Hrs, Time Clock GMT Min, and Time Clock GMT Sec.

Figures 1-7 show data from the full duration of the event flight, from 10:30:00 to 11:23:00 EDT. Figures 8-10 show data from the time around the engine event, from 11:03:25 to 11:04:15 EDT. Figure 11 shows a shorter duration time period around the engine event, from 11:03:30 to 11:03:50 EDT.

Figure 1 is a map overlay of the latitude and longitude data recorded during the event flight, shown in Google Earth. Note that atmospheric and lighting conditions in Google Earth may not be representative of those on the day of the event.

Figures 2 and 8 are of basic aircraft parameters including accelerations, pitch, roll, heading, etc.

Figures 3 and 9 are of flight control and control surface positions and forces.

Figures 4, 5, 6, 7, and 10 are of engine data.

Figure 11 shows parameters used to determine the timing of the fan blade out event and other associated aircraft events resulting from the engine event.

These figures are configured such that right turns are indicated by the trace moving toward the bottom of the page, left turns towards the top of the page, and nose up attitudes towards the top of the page.

Data show that the engines were started at around 10:31 EDT, number two (right) engine first and number one (left) engine second. The flaps were set at 5 degrees (deg) and the aircraft taxied for about 11 minutes before aligning with the runway heading and the engines began accelerating to takeoff power at 10:42:34. The aircraft accelerated, and pitch began to increase at 10:43:11 at a computed airspeed of 123 knots (kts). The gear weight on wheels signal transitioned from ground to air at 10:43:20, at a computed airspeed of 157 kts.

[2] GMT is Greenwich Mean Time which is also known as Coordinated Universal Time (UTC).

The aircraft climbed steadily for about seven minutes to a pressure altitude of about 17,250 feet (ft). Following two minutes at this altitude the aircraft began to climb again to a pressure altitude of 22,000 ft. After three minutes at 22,000 ft, at about 10:57, the aircraft began to climb again.

Using aircraft acceleration, pitch, roll, and engine data, the approximate time of the fan blade off event was 11:03:33.2. Pressure altitude at this time was about 32,648 ft. Engine 1 fan and core speeds decreased immediately after the event and engine 1 vibration levels were elevated. The engine 1 control recorded a flameout protection recovery mode active at 11:03:35 and remained in this mode until the engine 1 fuel switch position transitioned from Run to Cutoff at 11:04:09.

At 11:03:33.3 a discontinuity occurred in the data with missing data of at least 0.09 seconds. Using recorded GMT Seconds, it appeared that the 0.09 seconds of missing data and the total discontinuity spanned approximately the same duration. The discontinuity was likely due to a momentary power interruption to the recording system.

Immediately following the engine event, the aircraft began to roll to the left, reaching a peak recorded value of 41.3 degrees left roll 11 seconds after the discontinuity before coming back to a level attitude. Flight control position and force data showed that the left roll was uncommanded and pilot inputs and force were to the right.

At 11:03:39, approximately six seconds after the discontinuity, a Cabin Altitude Warning, signifying that the cabin altitude exceeded 10,000 ft, was recorded. At 11:03:43 the aircraft began a rapid descent with descent rates in excess of 5,000 feet per minute. The Cabin Altitude Warning stayed active until 11:12:24, when aircraft pressure altitude was about 9,150 ft.

At 11:03:48 an Engine 1 Fault Dispatch Level A fault was recorded. This fault was correlated to a T12 (fan bypass duct temperature) fault.

During the descent both the fan and the core of the damaged engine continued to windmill.

The aircraft touched down at about 11:20:30 with the flaps set at 5 degrees at approximately 171 kts. Reverse thrust was used on the right engine.

The corresponding tabular data used to create figures 1 to 11, including Time Clock GMT Hours, Time Clock GMT Minutes, and Time Clock GMT Seconds, are provided in electronic comma separated value (*.csv) format as attachment 1 to this report.

Figure 1. Map overlay of flight path with fan blade out location annotated.

Figure 2. Plot of basic parameters during entire flight.

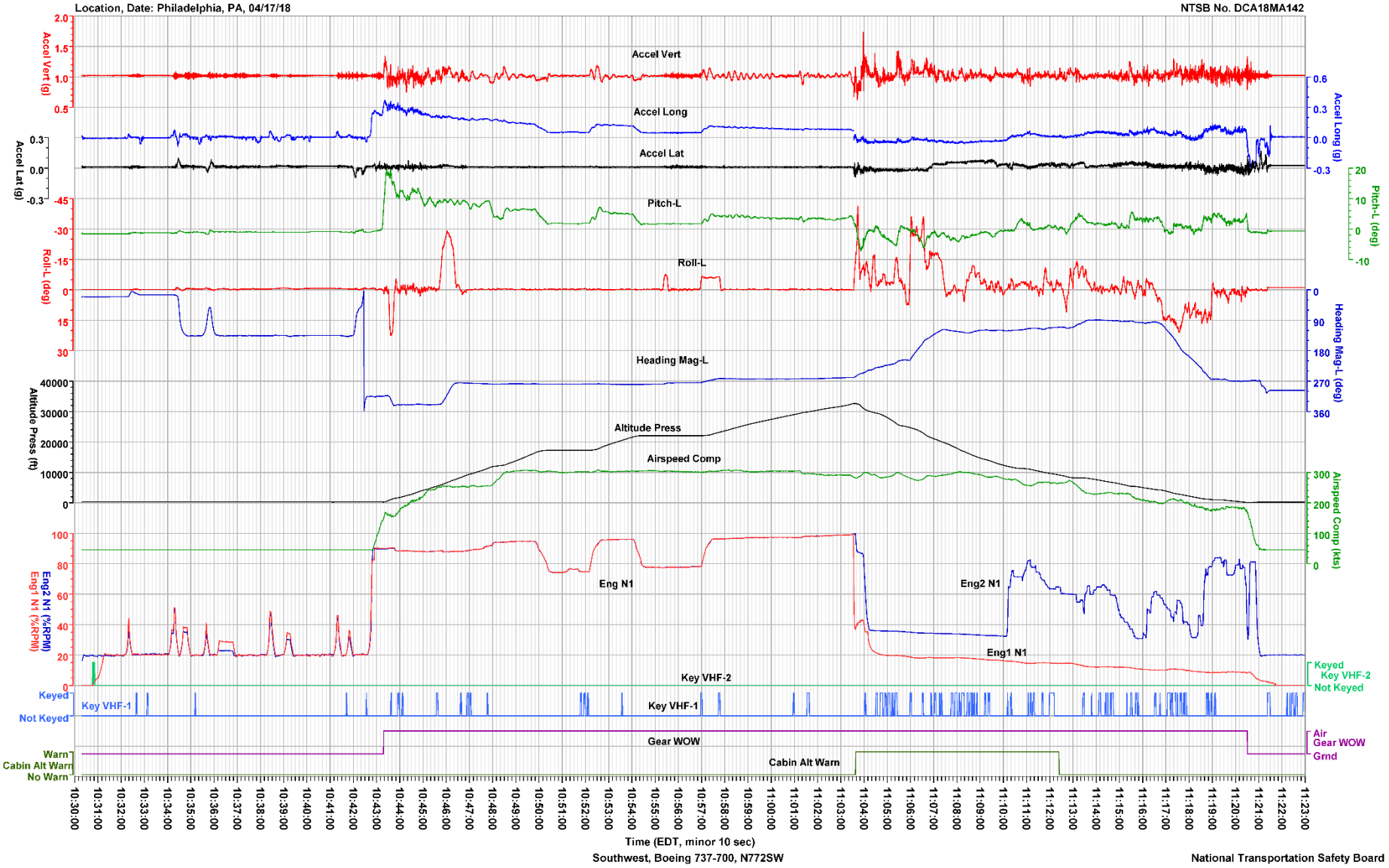


Figure 3. Plot of flight control positions and forces during entire flight.

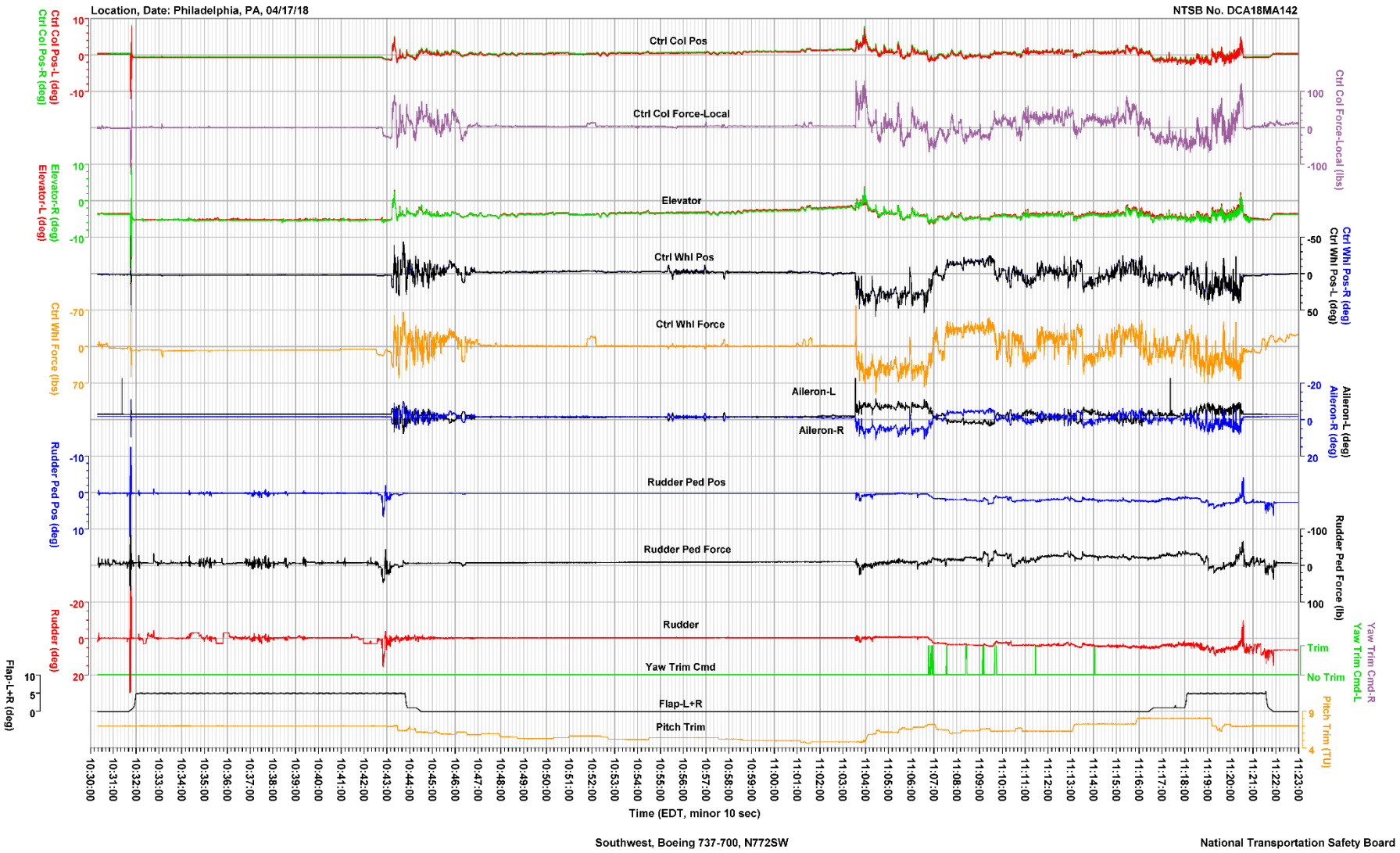


Figure 4. Plot of select engine parameters during entire flight.

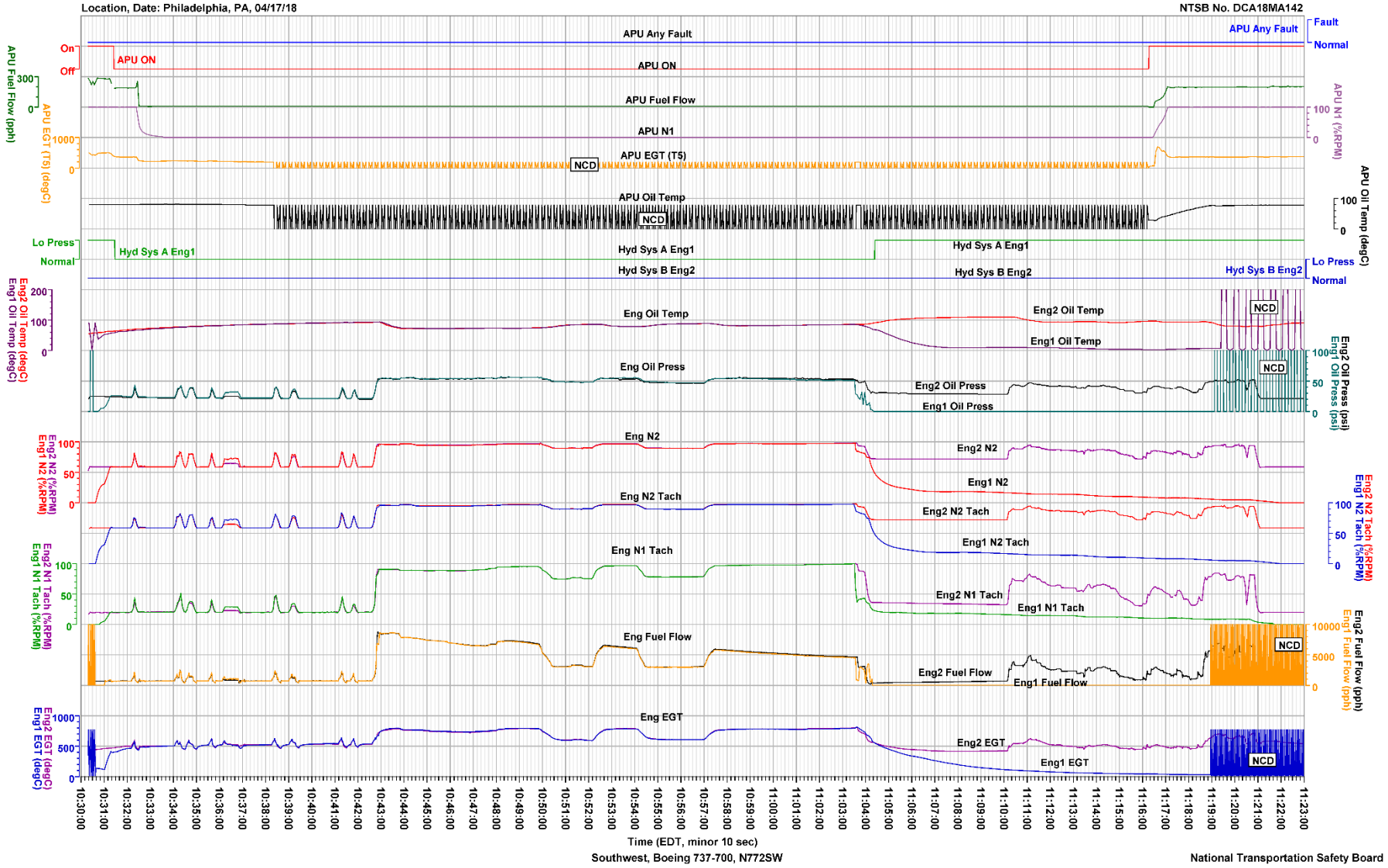


Figure 5. Plot of select engine discrete parameters during entire flight.

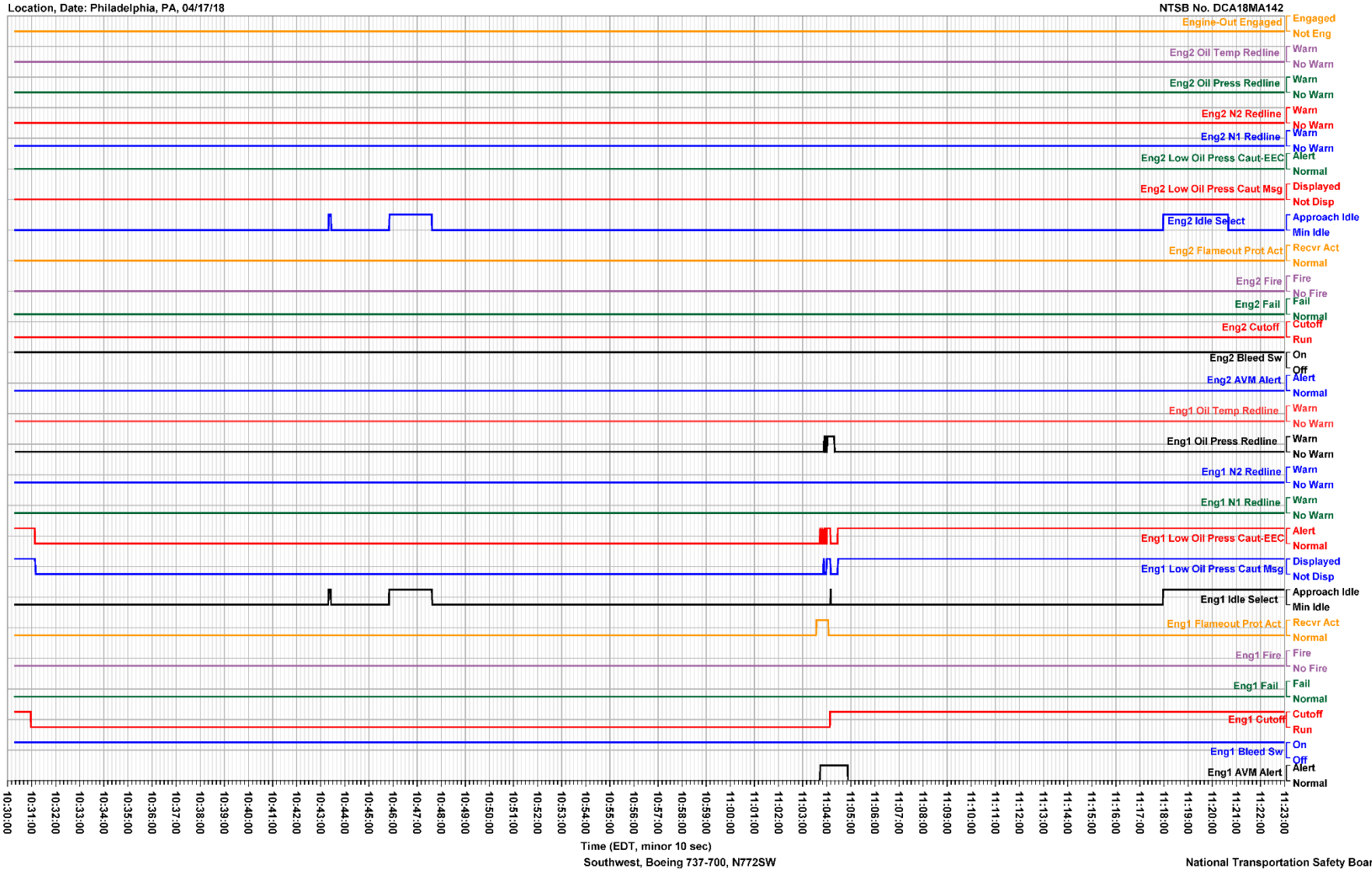


Figure 6. Plot of engine vibration parameters during entire flight.

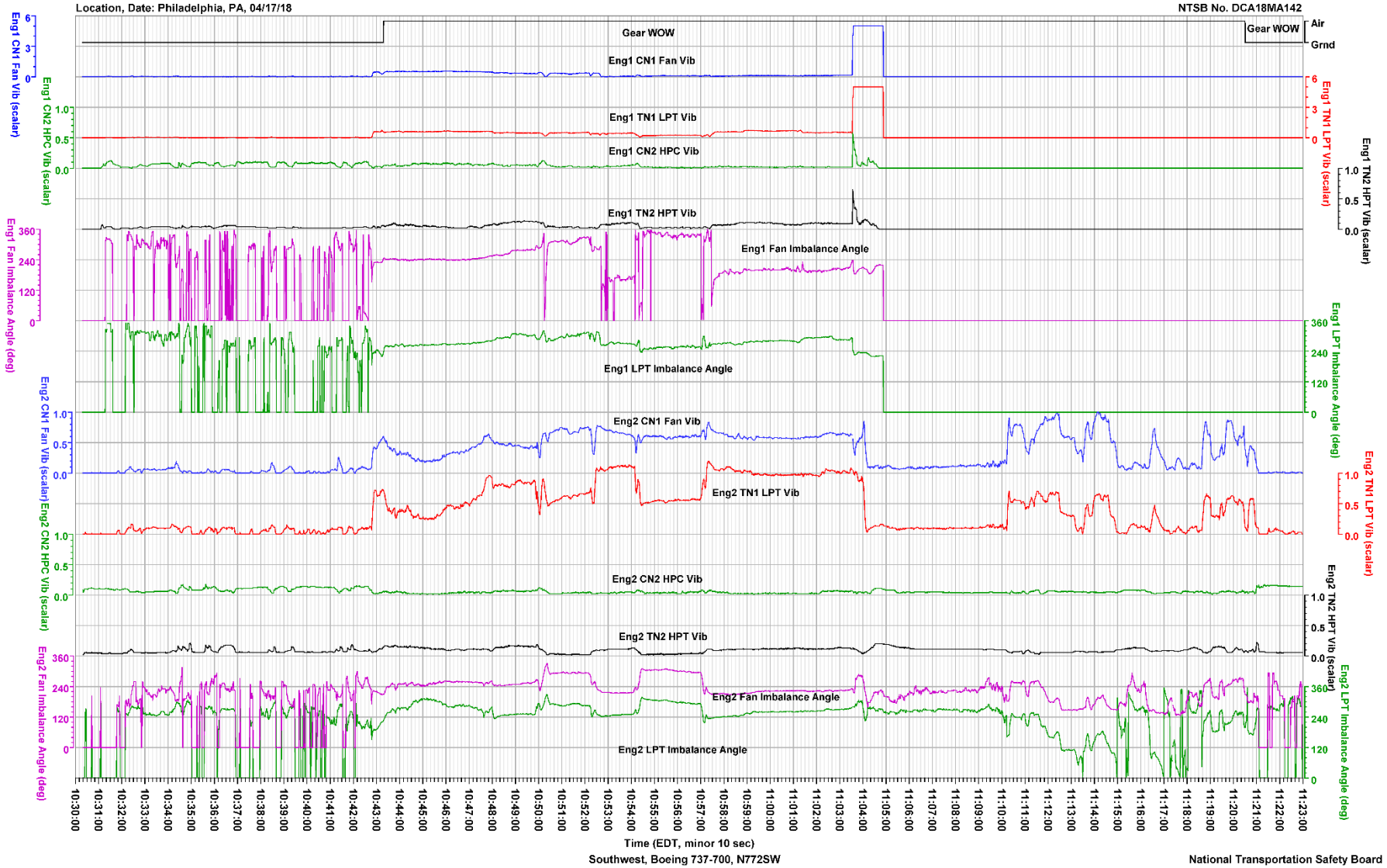


Figure 7. Plot of engine temperature and pressure parameters during entire flight.

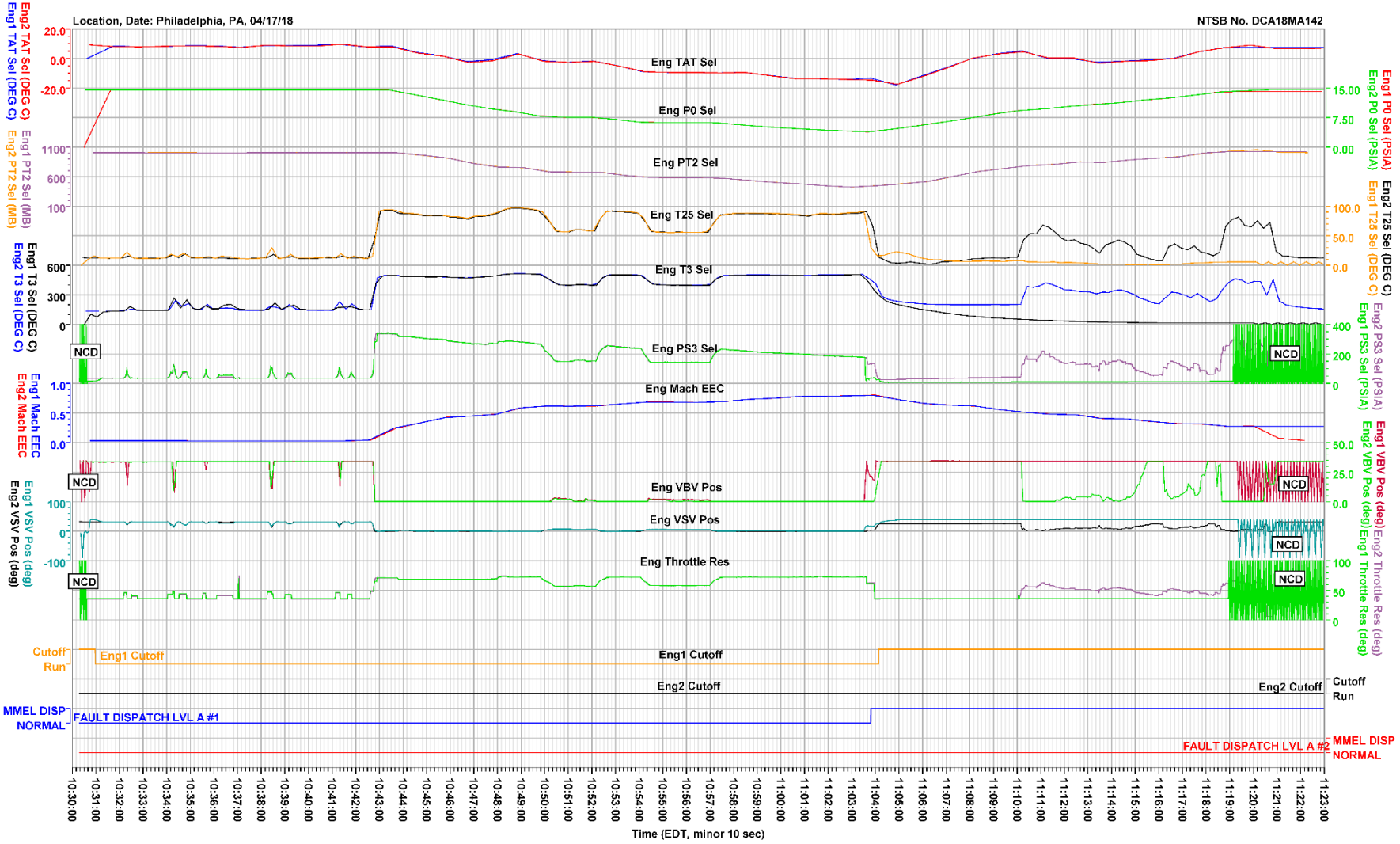


Figure 8. Plot of basic parameters around the time of the engine event.

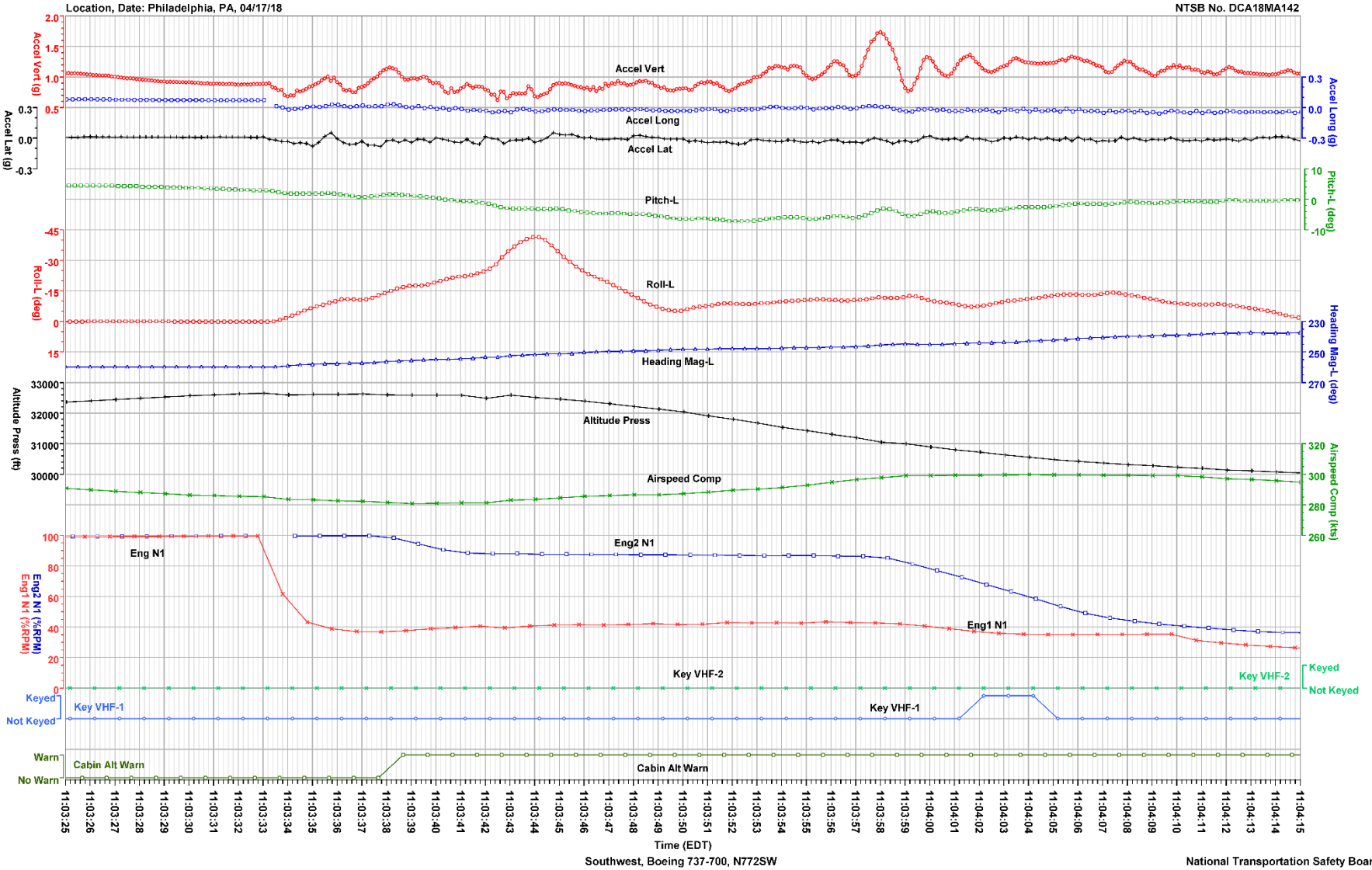


Figure 9. Plot of flight control parameters around the time of the engine event.

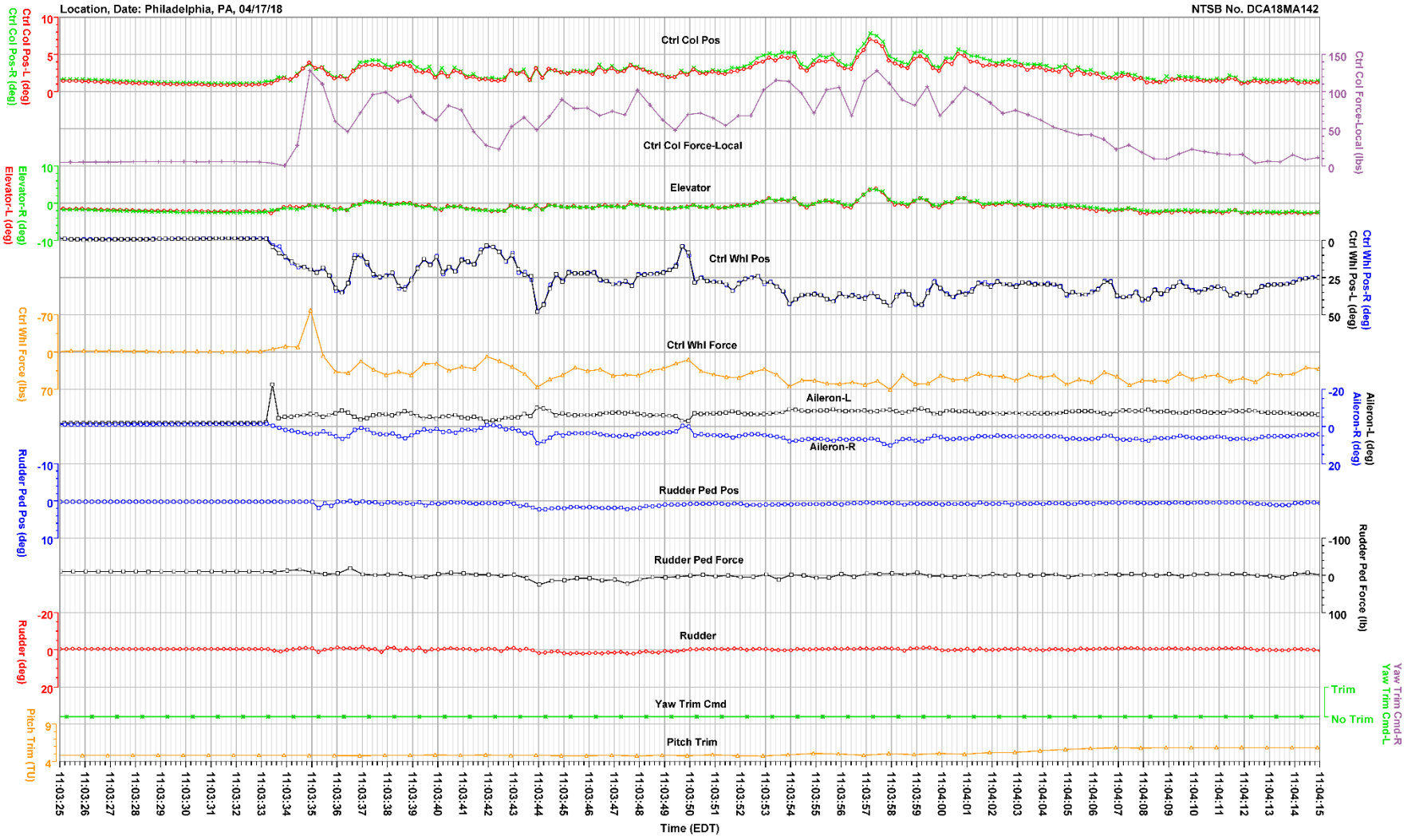


Figure 10. Plot of select engine parameters around the time of the engine event.

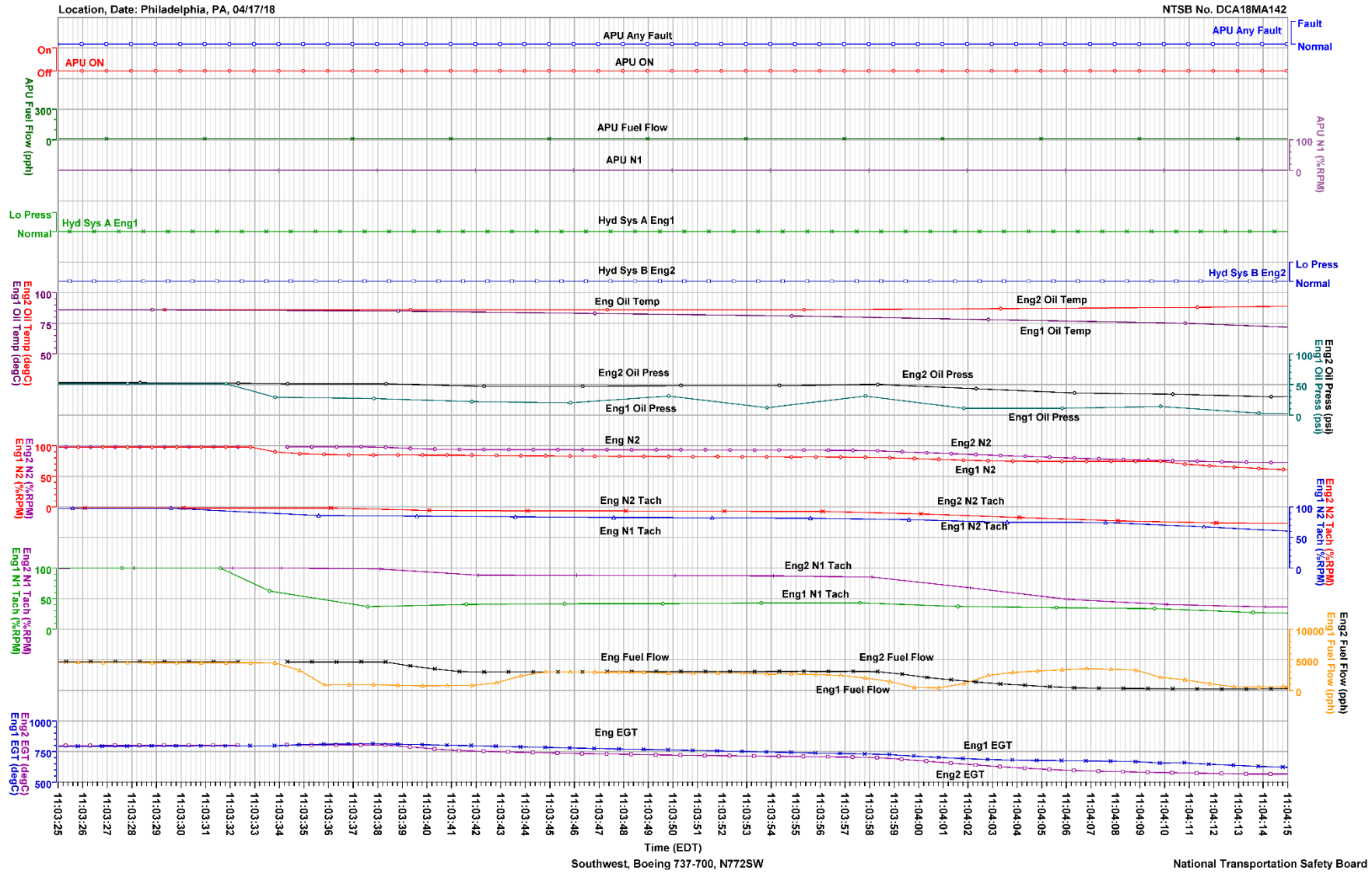
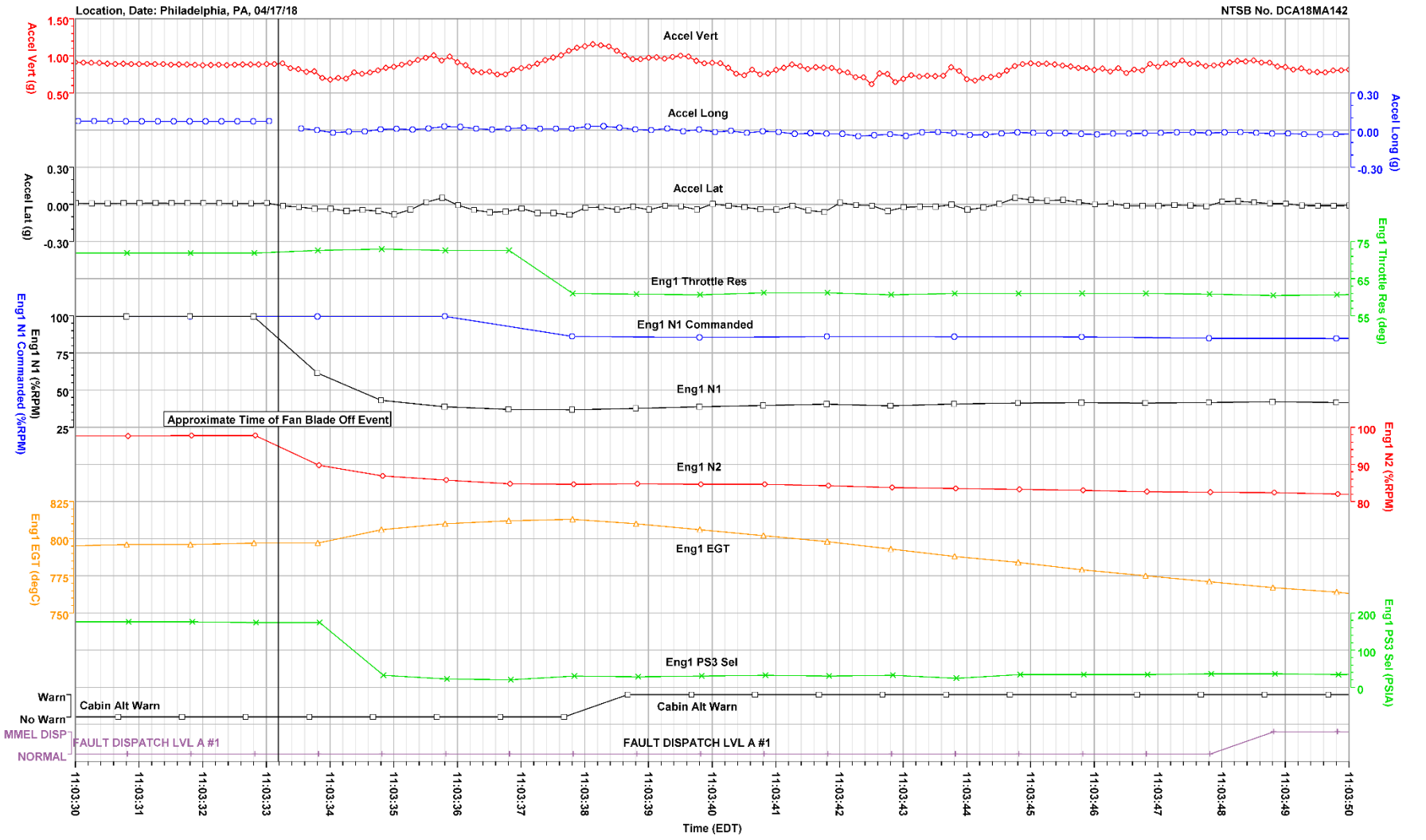


Figure 11. Plot of fan blade off and fault timing



APPENDIX A

This appendix describes the parameters provided and verified in this report. Table A-1 lists the plot/table labels, parameter names, and units. Additionally, table A-2 describes the unit and discrete abbreviations used in this report.

Table A-1. Verified and provided FDR parameters.

Plot/Table Labels	Parameter Names	Units
Accel Lat	Lateral Acceleration	g
Accel Long	Longitudinal Acceleration	g
Accel Vert	Vertical Acceleration	g
Aileron-L	Left Aileron Position	deg
Aileron-R	Right Aileron Position	deg
Airspeed Comp	Computed Airspeed	kts
Altitude Press	Pressure Altitude	ft
APU Any Fault	APU Fault Recorded	
APU EGT (T5)	APU Exhaust Gas Temperature	deg C
APU Fuel Flow	APU Fuel Flow	pph
APU N1	APU N1 Speed	%rpm
APU Oil Temp	APU Oil Temperature	deg C
APU On	APU Running	
Cabin Alt Warn	Cabin Altitude >10,000 ft	
Ctrl Col Force-Local	Local FCC Control Column Force	lbs
Ctrl Col Pos-L	Left Control Column Position	deg
Ctrl Col Pos-R	Right Control Column Position	deg
Ctrl Whl Force	Control Wheel Force	lbs
Ctrl Whl Pos-L	Left Control Wheel Position	deg
Ctrl Whl Pos-R	Right Control Wheel Position	deg
Elevator-L	Left Elevator Position	deg
Elevator-R	Right Elevator Position	deg
Eng1 AVM Alert	Left Engine Vibration Alert	
Eng1 Bleed Sw	Left Engine Bleed Switch	
Eng1 CN1 Fan Vib	Left Engine Fan Vibration Level	scalar
Eng1 CN2 HPC Vib	Left Engine High Pressure Compressor Vibration Level	scalar
Eng1 Cutoff	Left Engine Cutoff Switch Position	
Eng1 EGT	Left Engine Exhaust Gas Temperature	deg C
Eng1 Fail	Left Engine Failure Detected	
Eng1 Fan Imbalance Angle	Left Engine Calculated Fan Imbalance Angle	deg
Eng1 Fire	Left Engine Fire Detected	
Eng1 Flameout Prot Act	Left Engine Flameout Recovery Mode Active	
Eng1 Fuel Flow	Left Engine Fuel Flow	pph
Eng1 Idle Select	Left Engine Idle Mode Selected	
Eng1 Low Oil Press Caut EEC	Left Engine Oil Pressure Detected Low by EEC	
Eng1 Low Oil Press Caut Msg	Left Engine Oil Pressure Low Message Displayed	
Eng1 LPT Imbalance Angle	Left Engine Calculated Low Pressure Turbine Imbalance Angle	deg
Eng1 Mach EEC	Left Engine EEC Calculated Mach Number	mach
Eng1 N1	Left Engine Fan Speed	%rpm
Eng1 N1 Redline	Left Engine Fan Speed Exceeds Redline	
Eng1 N1 Tach	Left Engine Fan Speed from Tachometer	%rpm

Plot/Table Labels	Parameter Names	Units
Eng1 N2	Left Engine Core Speed	%rpm
Eng1 N2 Redline	Left Engine Core Speed Exceeds Redline	
Eng1 N2 Tach	Left Engine Core Speed from Tachometer	%rpm
Eng1 Oil Press	Left Engine Oil Pressure	psi
Eng1 Oil Press Redline	Left Engine Oil Pressure Exceeds Redline	
Eng1 Oil Temp	Left Engine Oil Temperature	deg C
Eng1 Oil Temp Redline	Left Engine Oil Temperature Exceeds Redline	
Eng1 P0 Sel	Left Engine Static Pressure	psi
Eng1 PS3 Sel	Left Engine Compressor Discharge Static Pressure	psia
Eng1 PT2 Sel	Left Engine Total Pressure	MB
Eng1 T25 Sel	Left Engine Compressor Inlet Temperature	deg C
Eng1 T3 Sel	Left Engine Compressor Discharge Temperature	deg C
Eng1 TAT Sel	Left Engine Total Air Temperature	deg C
Eng1 Throttle Res	Left Engine Throttle Resolver Position	deg
Eng1 TN1 LPT Vib	Left Engine Low Pressure Turbine Vibration Level	scalar
Eng1 TN2 HPT Vib	Left Engine High Pressure Turbine Vibration Level	scalar
Eng1 VBV Pos	Left Engine Variable Bleed Valve Position	deg
Eng1 VSV Pos	Left Engine Variable Stator Vane Position	deg
Eng2 AVM Alert	Right Engine Vibration Alert	
Eng2 Bleed Sw	Right Engine Bleed Switch	
Eng2 CN1 Fan Vib	Right Engine Fan Vibration Level	scalar
Eng2 CN2 HPC Vib	Right Engine High Pressure Compressor Vibration Level	scalar
Eng2 Cutoff	Right Engine Cutoff Switch Position	
Eng2 EGT	Right Engine Exhaust Gas Temperature	deg C
Eng2 Fail	Right Engine Failure Detected	
Eng2 Fan Imbalance Angle	Right Engine Calculated Fan Imbalance Angle	deg
Eng2 Fire	Right Engine Fire Detected	
Eng2 Flameout Prot Act	Right Engine Flameout Recovery Mode Active	
Eng2 Fuel Flow	Right Engine Fuel Flow	pph
Eng2 Idle Select	Right Engine Idle Mode Selected	
Eng2 Low Oil Press Caut EEC	Right Engine Oil Pressure Detected Low by EEC	
Eng2 Low Oil Press Caut Msg	Right Engine Oil Pressure Low Message Displayed	
Eng2 LPT Imbalance Angle	Right Engine Calculated Low Pressure Turbine Imbalance Angle	deg
Eng2 Mach EEC	Right Engine EEC Calculated Mach Number	mach
Eng2 N1	Right Engine Fan Speed	%rpm
Eng2 N1 Redline	Right Engine Fan Speed Exceeds Redline	
Eng2 N1 Tach	Right Engine Fan Speed from Tachometer	%rpm
Eng2 N2	Right Engine Core Speed	%rpm
Eng2 N2 Redline	Right Engine Core Speed Exceeds Redline	
Eng2 N2 Tach	Right Engine Core Speed from Tachometer	%rpm
Eng2 Oil Press	Right Engine Oil Pressure	psi
Eng2 Oil Press Redline	Right Engine Oil Pressure Exceeds Redline	
Eng2 Oil Temp	Right Engine Oil Temperature	deg C
Eng2 Oil Temp Redline	Right Engine Oil Temperature Exceeds Redline	
Eng2 P0 Sel	Right Engine Static Pressure	psi
Eng2 PS3 Sel	Right Engine Compressor Discharge Static Pressure	psia
Eng2 PT2 Sel	Right Engine Total Pressure	MB
Eng2 T25 Sel	Right Engine Compressor Inlet Temperature	deg C
Eng2 T3 Sel	Right Engine Compressor Discharge Temperature	deg C

Plot/Table Labels	Parameter Names	Units
Eng2 TAT Sel	Right Engine Total Air Temperature	deg C
Eng2 Throttle Res	Right Engine Throttle Resolver Position	deg
Eng2 TN1 LPT Vib	Right Engine Low Pressure Turbine Vibration Level	scalar
Eng2 TN2 HPT Vib	Right Engine High Pressure Turbine Vibration Level	scalar
Eng2 VBV Pos	Right Engine Variable Bleed Valve Position	deg
Eng2 VSV Pos	Right Engine Variable Stator Vane Position	deg
Engine Out Engaged	Aircraft Engine Out Logic Engaged	
Fault Disptch Lvl A #1	Left Engine Time-Limited Dispatch Fault Recorded	
Fault Disptch Lvl A #2	Right Engine Time-Limited Dispatch Fault Recorded	
Flap-L+R	Flap Position	deg
Gear WOW	Landing Gear Weight on Wheels	
Heading Mag-L	Magnetic Heading	deg
Hyd Sys A Eng1	Left Engine Hydraulic System A Low Pressure	
Hyd Sys B Eng2	Right Engine Hydraulic System B Low Pressure	
Key VHF-1	Left VHF Radio Keyed	
Key VHF-2	Right VHF Radio Keyed	
Latitude	Latitude	deg
Longitude	Longitude	deg
Pitch Trim	Pitch Trim Position	TU
Pitch-L	Pitch Angle	deg
Roll-L	Roll Angle	deg
Rudder	Rudder Position	deg
Rudder Ped Force	Rudder Pedal Force	deg
Rudder Ped Pos	Rudder Pedal Position	deg
Time Clock GMT Hours	GMT Hours	hrs
Time Clock GMT Minutes	GMT Minutes	min
Time Clock GMT Sec	GMT Seconds	sec
Yaw Trim Cmd-L	Yaw Trim Commanded from Left	
Yaw Trim Cmd-R	Yaw Trim Commanded from Right	

NOTE: This FDR records pressure altitude, which is based on a standard altimeter setting of 29.92 inches of mercury (in Hg). The pressure altitude information presented in the FDR plots and in the electronic data has not been corrected for the local altimeter setting at the time of the event.

NOTE: Parameters with a blank unit description in table A-1 are discretes. A discrete is typically a 1-bit parameter that is either a 0 state or a 1 state where each state is uniquely defined for each parameter.

Table A-2. Unit and discrete abbreviations.

Units and Abbreviations	Descriptions
%rpm	percent revolutions per minute
APU	Auxiliary Power Unit
deg	degrees
deg C	degrees Celsius
Disp	Dispatch
EEC	Electronic Engine Controller
Eng	Engine
FCC	Flight Control Computer
ft	feet
GMT	Greenwich Mean Time
Grnd	Ground
hrs	hours
kts	knots
lbs	pounds
MB	millibars
min	minutes
Min	Minimum
MMEL	Master Minimum Equipment List
NCD	Non-Computed Data
pph	pounds per hour
psi	pounds per square inch
psia	pounds per square inch, absolute
Recvr Act	Recovery Active
sec	seconds
SW	Switch
TAT	Total Air Temperature
TU	Trim Units